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RADON PREVENTION IN NEW CONSTRUCTION IN FINLAND: A NATIONWIDE SAMPLE SURVEY IN 2009

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The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003–2004. Thereafter, preventive measures have become more common and effective and indoor radon concentrations have been markedly reduced. In this study, the indoor radon concentration was measured in 1500 new low-rise residential houses. The houses were randomly selected and represented 7 % of the houses that received building permission in 2006. The average radon concentration of all the houses measured, which were completed in 2006–2008, was 95 Bq m^{-3}, the median being 58 Bq m^{-3}. The average was 33 % lower than in houses completed in 2000–2005. The decrease was 47 % in provinces with the highest indoor radon concentration and 26 % elsewhere in the country. In houses with a slab-on-ground foundation that had both passive radon piping and sealing measures carried out using a strip of bitumen felt in the joint between the foundation wall and floor slab, the radon concentration was on average reduced by 57 % compared with houses with no preventive measures. Preventive measures were taken nationwide in 54 % of detached houses and in provinces with the highest radon concentration in 92 % of houses.

INTRODUCTION

Finland, together with the Nordic countries of Sweden and Norway, is among those countries having high indoor radon concentrations. The percentage of residential houses exceeding the reference level for new construction, 200 Bq m^{-3}, was 16 % in a national random sample survey carried out in 2006–2007[1]. The national average and median for low-rise residential buildings were 121 and 75 Bq m^{-3}. In 6 of the 20 Finnish provinces, the percentage of houses exceeding 200 Bq m^{-3} was 25–50 %, the median concentration ranging from 120 to 200 Bq m^{-3}. Permeable soil types, the uranium concentration in soils and the cold climate are the main reasons for elevated indoor radon concentrations.

Slab-on-ground is by far the most prevalent type of foundation for newly constructed low-rise residential houses in Finland, accounting for 65 % of houses. The key feature of this foundation type regarding radon prevention is the gap between the floor slab and foundation wall (Figure 1). This gap promotes the flow of radon-bearing soil air into living spaces. The prevalence of semi-basement houses and basement houses in the housing stock is 15 %. These foundation types have a similar joint between the floor and foundation wall at a ground level to that in slab-on-ground houses. Therefore, altogether 80 % of Finnish low-rise residential buildings represent a foundation type with a high radon risk. Preventive measures in new construction are thus an essential part of attempts to reduce radon concentrations in Finnish housing.

The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003–2004[2–4]. Thereafter, preventive measures have become more common and prevention practices more effective. The aim of this study was to survey the renewed preventive measures in new construction and their effect on the national radon situation.

Regulations and guidance

The first guidance for the nationwide use of radon prevention in new building was issued in 1996. This guidance, together with new municipal building regulations, resulted in an increased use of preparatory radon piping beneath floor slabs. This guidance was revised in 2003[2, 3]. Concurrently, in 2004, the building code for radon prevention was revised[4]. Subsequently, preventive measures have become more common and prevention practices more effective. The building code for foundation structures requires that radon should be taken into account in all construction work in Finland. Houses should be designed and constructed so that the indoor radon concentration is kept <200 Bq m^{-3}.

The guidance for radon-resistant new construction focuses on practices needed in houses with slab-on-ground foundations as well as in houses with walls in contact with soil. The essential preventive measures are the installation of preparatory radon piping below the floor slab and sealing of the joint between the floor slab and the foundation wall using a strip of bitumen felt (Figures 2–4). In a passive radon piping system, the discharge is open above roof. The temperature difference and wind create an air flow, which reduces the radon concentration in the pore air of the sub-slab gravel. When needed, one can install a radon fan in the discharge of the piping which, when active, effectively reduces the indoor radon concentration.

MATERIALS AND METHODS

New construction survey (2009)

In this survey, the indoor radon concentration was measured in 1561 new low-rise residential houses[5]. The houses were randomly selected from the database of the Population Register Centre of Finland and represented 7 % of the 22 716 houses that received

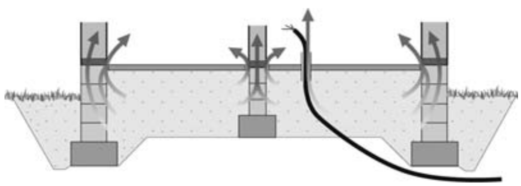

Figure 1. Entry routes of soil air in a Finnish slab-on-ground foundation. The foundation wall is constructed of permeable light-weight concrete blocks.

Figure 3. Installation of a strip of bitumen felt in the joint of foundation wall and floor slab according to the Finnish guidelines.

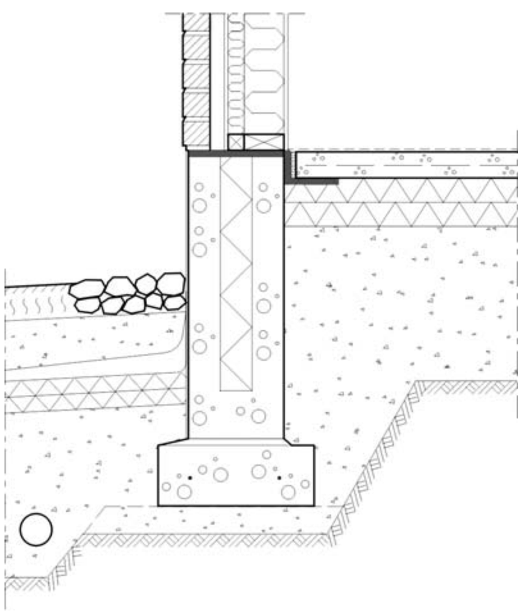

Figure 2. Sealing of the gap between the foundation wall and floor slab according to the Finnish guidelines.

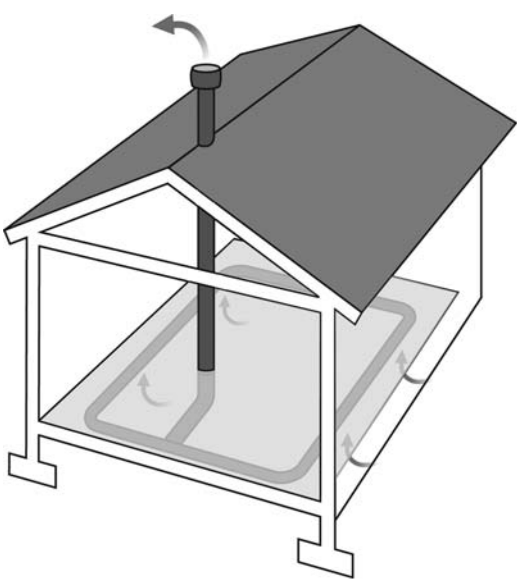

Figure 4. Radon piping in the Finnish radon prevention guidelines.

building permission in 2006. The selected houses were occupied by November 2008. Altogether, 3000 dwellings were selected for this study, and an invitation to participate in the study was sent to the house owners. Radon measurements lasted for 2 months from March to May 2009. The alpha track detector that was used records the average radon concentration over the measurement period. The standard questionnaire of the STUK radon measurement service was used to gather information on the foundation type and other house characteristics. A special questionnaire for radon prevention illustrated, for example, with Figures 2–4, was designed to obtain information on preventive measures taken, sealing work and the installation of radon piping.

In the new construction survey, a total of 1561 low-rise residential houses were measured. This includes 1070 detached houses and 491 dwellings in terraced houses (n=333) and semi-detached houses (n=158).

Sample survey (2006)

The results of the new construction survey (2009) were compared with the previous nationwide survey of the total housing stock. This former survey is referred to below as the sample survey (2006)[(1)]. In the survey, carried out in 2006–2007, 6000 Finnish house owners were selected using simple random sampling from the population registry. The radon measurements were carried out using alpha track detectors in two half-year periods, the first from May to October 2006 (summer measurement) and the second from November 2006 to April 2007 (winter measurement). Information on the dwelling construction was collected using the same questionnaire as in this new construction study. The final participation rate with valid measurements was 48 % (2866 houses). The annual mean radon concentration for each dwelling was calculated as an arithmetic mean weighted according to the lengths of the two measurement periods. The final national statistics were calculated by weighting the annual means according to the number of inhabitants of houses and flats in each province.

The weighting was carried out because the participation rate was remarkably lower in flats (31 %) than in low-rise houses (58 %) and because the participation rate varied (46–59 %) in the provinces with varying indoor radon levels. The average radon concentration in flats (49 Bq m^{-3}) was remarkably lower than that in low-rise houses (121 Bq m^{-3}). The nationwide average for all 2866 houses was 96 Bq m^{-3}. In comparison with the new construction survey, results from 2267 residents living in low-rise residential houses (detached, terraced or semi-detached houses) were used.

RESULTS

Participation

Altogether, 1862 of 3000 house owners (62 %) expressed their willingness to participate in the new construction survey[(5)]. They also received a radon detector by mail. A total of 1705 detectors were returned. Finally, 1561 measurements were accepted. The accepted length of measurement was 28–100 d. Summer concentrations are lower than winter and spring concentrations. Therefore, long measurement periods are not comparable and were rejected. The median length of the measurement period was 62 d, with 1 and 99 % percentiles of 53 and 96 d, respectively. The final overall participation rate was thus 52 %. The participation rate in the 20 provinces varied from 43 to 68 %. No clear correlation between the provincial indoor radon concentration and participation was observed.

Radon concentration

The average radon concentration of all low-rise residential houses measured in the new construction survey was 95 Bq m^{-3}, the median being 58 Bq m^{-3}. The houses were completed in 2006–2008. Weighting of the results according to the number of inhabitants in low-rise residential houses in each province did not alter these results. The results were therefore comparable with those of the previous sample survey (2006), which was based on a random population sample. The geographical distributions of houses in these two surveys were quite similar.

Comparison of the survey results revealed that the average and median radon values in the new construction survey (2009) were 21 and 23 % lower than the respective annual average figures in the sample survey (2006) (Table 1). The percentage of houses exceeding the reference level of 200 Bq m^{-3} had also markedly decreased from 15.1 to 10.6 %.

The average temperature during measurements for the new construction survey was 2.2°C, compared with 0.1°C in the winter and 14.6°C in the summer for the measurements of the sample survey (2006). To determine the effect of the introduction of a new building code, the results from the new construction survey were compared with those from the winter measurements of the 2006 survey, because the weather conditions were most similar. The average temperature during the winter measurements of the 2006 survey was slightly lower than the average temperature during the new construction survey, this is likely to lead to a slight overestimate of the differences caused by the changes to the building code. However, it was decided that the winter concentrations of the sample survey (2006) were used as the ‘best reference value’.

Table 1. Indoor radon concentration in low-rise residential houses completed in 2006–2008 in the new construction survey 2009 and comparison with the annual average values of the previous national sample survey (2006).

Parameter	New construction survey (2009)	Sample survey (2006), annual average	Decrease compared with the sample survey (2006), % or pp[a]
Number of houses	1561	2267	
Radon concentration			
Average Bq m^{-3}	95	121	21 %
Median Bq m^{-3}	58	75	23 %
Minimum Bq m^{-3}	1	5	
Maximum Bq m^{-3}	4310	2269	
Percentage exceeding 100 Bq m^{-3}	29.4	38.9	9.5 pp
Percentage exceeding 200 Bq m^{-3}	10.6	15.1	4.5 pp
Percentage exceeding 400 Bq m^{-3}	2.1	3.8	1.7 pp

[a]Percentage points (pp) are the unit for the arithmetic difference of two percentages. The usual percentage change (or difference) represents the relative change between the old value and the new one.

Table 2. Average and median radon concentration and percentage of houses exceeding 200 Bq m^{-3} in the new construction survey (2009) for the six provinces of Finland with the highest radon concentration (Zone 1) and elsewhere in the country (Zone 2) and comparison with the winter measurement of the nationwide sample survey (2006).

Survey and region	Radon concentration, Bq m^{-3} (% or percentage points, pp)		
	Average	Median	Percentage exceeding 200 Bq m^{-3}
New construction survey (2009)			
Zone 1	125 (47 %)	74 (55 %)	16.5 (25 pp)
Zone 2	83 (26 %)	53 (28 %)	8.4 (3.8 pp)
Whole country	95 (33 %)	58 (33 %)	10.6 (8.8 pp)
Sample survey (2006), winter concentration			
Zone 1	237	166	41.9
Zone 2	112	74	12.2
Whole country	142	87	19.4

Zone 1: provinces of Itä-Uusimaa, Kymenlaakso, Päijät-Häme, Pirkanmaa, Etelä-Karjala and Kanta-Häme; Zone 2: other provinces.

Table 3. Average and median radon concentration and the percentage exceeding 200 Bq m^{-3} in low-rise residential houses with different foundation types, new construction survey (2009).

Foundation type	Number of houses	Radon concentration (Bq m^{-3})		
		Average	Median	Percentage exceeding 200 Bq m^{-3}
Slab-on-ground	798	97	68	10.7
Monolithic slab[a]	18	36	27	0
Crawl space	231	43	29	2.6
Semi-basement and basement	193	161	97	22.3
No information	321	89	54	9.7
Total	1561	95	58	10.6

[a]Houses with a foundation type confirmed by telephone included.

Analysis of the results from the new construction survey revealed regional differences in radon prevention activity, which was clearly higher in the provinces with the highest indoor radon concentrations (Table 4). Therefore, comparison with the previous housing stock (sample survey 2006) was carried out in two zones: the six provinces with the highest radon concentrations (Zone 1) and elsewhere in the country (Zone 2, Table 2). The average radon concentration for the whole country in the new construction survey (2009) was 33 % lower than the winter concentration of the sample survey (2006) (Table 2). In the high radon zone, the decrease was 47 % and elsewhere in the country 26 %.

Effect of foundation type

Radon concentrations were by far the lowest in houses with a monolithic concrete slab and those with a crawl space. In both of these classes, the average radon concentration was <45 Bq m^{-3} and the median <30 Bq m^{-3} (Table 3). A monolithic slab is difficult to distinguish from a normal slab-on-ground foundation. Therefore, the owners of all the houses accepted in the analysis were telephoned to confirm the type of foundation, and ~50 % of the houses had normal slabs. In houses with a slab-on-ground foundation, the average radon concentration was 97 Bq m^{-3} and the median 68 Bq m^{-3}. In semi-basement and basement houses with walls in contact with soil, the average and median were 161 and 97 Bq m^{-3}, respectively, which was >50 % higher than in houses with a slab-on-ground construction. The main reason for these elevated values was the defective measures for radon prevention in the block walls in contact with soil. The leakage of radon-bearing soil air through walls in contact with soil can also be seen in the percentage of houses exceeding the reference level of 200 Bq m^{-3}. This figure was 22 %, as compared with 11 % for low-rise residential houses with slab-on-ground foundations.

Prevention activity

Radon-resistant preventive measures were classified according to the questionnaire data into four categories presented in Table 5:

(1) no measures;
(2) passive radon piping (discharge open above roof) and sealing with bitumen felt;
(3) passive radon piping with no sealing;
(4) radon piping either open or capped; the house owner could not confirm whether the discharge was open above the roof or capped.

Table 4. Radon preventive measures in the provinces of Finland with the highest radon concentrations (Zone 1) and elsewhere in the country (Zone 2) for detached houses with slab-on-ground foundations, new construction survey (2009).

Provinces	Passive radon piping installed (%)	Radon piping and bitumen felt sealing installed (%)
Zone 1: Itä-Uusimaa, Kymenlaakso, Päijät-Häme, Pirkanmaa, Etelä-Karjala ja Kanta-Häme	92	83
Zone 2: elsewhere in the country	38	32
Whole country	54	46

Table 5. Effect of preventive measures on the indoor radon concentration of detached houses with slab-on-ground foundations in the new construction survey (2009).

Feature	Preventive measures			
	No measures	Passive piping and sealing	Passive piping	Passive piping or closed piping
Number of houses	230	166	111	55
Radon concentration (average Bq m^{-3})	90	82	98	99
Radon concentration (median Bq m^{-3})	68	53	59	86
Radon concentration, local reference value (median, Bq m^{-3})[a]	58	128	106	112
Ratio of radon concentration to local reference value (median)	1.19	0.46	0.56	0.67
Regression factor[b]	1.27	0.54	0.76	0.78
Radon reduction (%, 95% confidence limits)[c]	0	57 (43–71 %)	41 (24–58 %)	39 (20–58 %)
Percentage exceeding 200 Bq m^{-3} in 2009 study (%)	8	8	14	11
Percentage of local reference values exceeding 200 Bq m^{-3} (%)	7	29	26	24
Percentage exceeding 400 Bq m^{-3} in 2009 study (%)	1.3	1.2	1.8	0
Percentage of local reference values exceeding 400 Bq m^{-3} (%)	1.4	9.7	8.1	7.9

The results are compared with the local reference values from the national database of Radiation and Nuclear Safety Authority (STUK).
[a]Median of the measurements carried out in the postal code area, from the STUK database. If the number of measurements was below 10, the municipal median was used.
[b]Coefficient from linear regression analysis. Ratio of the measured radon concentration to the local reference value. The intercept term is set to zero.
[c]Radon reduction for the preventive measures has been calculated as the ratio of the regression coefficient to the coefficient of the 'No measures' class. The confidence limits have been calculated by summing the 2 STD errors in quadrature with the 'No measures' class.

For questions concerning radon piping and sealing, 70 % of participants in terraced houses responded 'Don't know' or did not provide a response on the form. In detached houses, the corresponding percentage was only 30 %. Similarly, the questionnaire data concerning the foundation type were quite defective for terraced houses (not completed in 48 % of cases) compared with detached houses (8 %). Due to the defects in data for terraced houses, the analysis of radon prevention was only carried out for detached houses.

Table 4 summarises the prevention activity in the whole country and in the two radon zones. Preventive measures had been carried out in 54 % of detached houses with slab-on-ground foundations. This percentage was 92 % in the six provinces with the highest indoor radon concentration and 38 % elsewhere in the country. In comparison with the 2006 random sample survey, the new regulations issued in 2003–2004 have doubled the level of prevention activity nationwide.

Impact of radon-resistant new construction

The impact of preventive measures was assessed through a comparison of indoor radon concentrations in houses with prevention and with no preventive measures. In this comparison, local reference values from the indoor radon database, including 87 000 houses throughout Finland, were also utilised[6]. The reference values used in the analysis were median radon concentrations of the postal code areas or percentages exceeding 200 Bq m^{-3} in the area. If the number of measurements in the area was below 10, the corresponding municipal values were used.

The effect of preventive measures on radon concentration was estimated by using regression analysis in which radon concentrations in new construction were compared with the local reference values. The final radon reduction for prevention measures was calculated as the ratio of regression coefficients to the coefficient of the 'no measures' class. This practice takes into account the systematic difference between the study data and the reference data.

In detached houses with slab-on-ground foundations, passive radon piping and the installation of a strip of bitumen felt reduced the indoor radon concentration by 57 % (Table 5). For this group, the ratio of the radon concentration to the local reference value was 0.46. Figure 5 illustrates the distribution of radon concentrations versus local reference

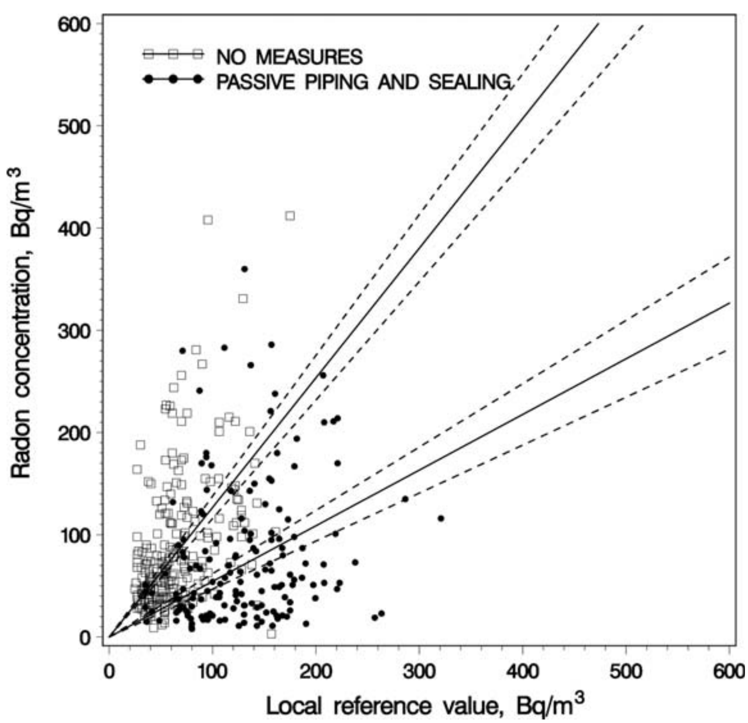

Figure 5. Radon concentration in the study houses and local reference values, new construction survey 2009. Regression lines are fitted for houses without preventive measures and houses with passive radon piping and sealing carried with a strip of bitumen felt.

values and the corresponding regression lines. In this group, the effect of prevention can also be clearly seen in the percentage of houses exceeding the reference level. In houses that had taken preventive measures, the percentage exceeding this level was 8 %. In relation to the local reference values, this percentage was 29 %. The average reduction for radon piping with no sealing measures was 41 % (Table 5).

For the 'no measures' class, both the median ratio of the radon concentration to local reference values (1.19) and the regression coefficient (1.27) were above unity. In addition to statistical uncertainty, this can be explained by the fact that local reference values are annual average radon concentrations calculated by multiplying the results for the heating season (November–April) by a factor of 0.85. The March–April measurements of this survey better represent heating season measurements than the annual average.

In considering the small difference between the houses with passive piping and sealing and those with passive piping alone, it should be noted that sealing work had often been defective due to non-sealed pipe penetrations and defects in bitumen felt installation.

In the case of basement and semi-basement houses, the analysis of radon reduction gave a median reduction efficiency of 30 % for houses with radon piping installed. The confidence limits were much wider than in the results for detached houses. This was due to the low number of houses and because sealing of the walls of porous concrete blocks in contact with soil is a very demanding task. The efficiency of passive radon piping is also lower in houses of this type. In these houses, radon entry through block walls is the main factor causing the elevated radon concentrations. Concentrations exceeding the reference level were also most common in semi-basement and basement houses (Table 3).

Ventilation strategy

Ventilation strategies and their prevalence in houses of different ages may also contribute to the changes in radon concentrations. Natural ventilation was the prevailing strategy until the 1980s (Table 6)[1]. Since then, the use of mechanical ventilation has taken the leading role, initially mechanical exhaust ventilation (MEV) (in the 1980s) and then mechanical supply and exhaust ventilation (MSEV). The development in terraced houses has been slower. In terraced houses built in 2000–2005 the prevalence of MSEV was 45 %, while in detached houses the prevalence was 76 %. In 2004, the building code for energy-saving requirements was renovated. Thereafter, the building industry was forced to introduce MSEV installations with heat recovery properties. This resulted in an MSEV prevalence of close to 100 % in all low-rise residential buildings completed in 2006–2008.

On the basis of the previous random sample survey (2006), radon concentrations in houses with MSEV are on average 20 % lower than in houses with natural ventilation and 30 % lower than in MEV houses[1]. The difference in radon

Table 6. Prevalence of ventilation strategies in Finnish detached houses (DH) and terraced houses and semi-detached houses (TSH) until 2005 based on the previous national sample survey (2006), and in those constructed between 2006 and 2008 based on the new construction survey (2009).

Survey and construction period	Prevalence of air exchange strategies (%)					
	Natural		Mechanical exhaust, MEV		Mechanical supply and exhaust, MSEV	
Sample survey (2006)	DH	TSH	DH	TSH	Detached houses	Terraced and semi-detached
–1949	88	68	7	32	6	—
1950–1959	93	100	3	—	4	—
1960–1969	95	78	3	22	2	—
1970–1979	83	74	14	22	4	4
1980–1989	42	45	19	43	38	12
1990–1999	19	9	29	67	52	24
2000–2005	9	4	15	51	76	45
New construction survey (2009)						
2006–2008	1	1	6[a]	6[a]	93	93

[a]Telephone calls confirmed that nearly all MEV systems in TSHs and approximately half of those in DHs were in fact of the MSEV type.

concentrations in MSEV houses compared with MEV is due to underpressure levels typically 2–5 and 5–10 Pa, respectively. In the analysis of radon reduction by different preventive measures, the prevalence of MSEV was close to 100 % in all prevention groups and in the 'no measures' group. In addition, the calculation method takes into account the systematic differences between the newly constructed houses and reference houses.

COMPARISON WITH THE PREVIOUS HOUSING STOCK

Indoor radon concentrations in low-rise residential houses grouped according to the year of construction are presented in Figure 6. The statistics for the years 1949–2005 are from the previous sample survey (2006) and the last results for 2006–2008 from this new construction survey. The average and median radon concentration in houses completed in 2000–2005 were quite close to the corresponding figures for all houses built before 2006. Therefore, the comparison of radon concentrations in new construction with the housing stock built before 2006 can also be applied to houses built in 2000–2005.

The annual average radon concentrations recorded in the sample survey (2006) (Table 1) have been used in Figure 6. Therefore, the change in radon concentrations from 2000–2005 to 2006–2008 is underestimated. On the other hand, a comparison based on the winter concentrations of the 2006 sample survey would slightly overestimate the difference, as explained above. When estimating the decrease in radon indoor concentrations in the new construction survey compared with the sample survey (2006), the winter concentrations (Table 2) have been used as the 'best reference value'.

As a summary, the nationwide average radon concentration in new construction was 33 % lower than in houses completed in 2000–2005. The decrease was 47 % in those provinces with the highest indoor radon concentrations and 26 % elsewhere in the country. The nationwide decrease compared with houses completed in 1980–1999 was 45 %.

COMPARISON WITH OTHER SURVEYS

Research into radon prevention and its impact on the national radon situation is a new research area, and few representative studies have been carried out. The present study is probably the first one based on a random national sample.

In the UK, the use of membranes resulted in a reduction of ~50 % in radon levels for both block and beam (under floor ventilation) and *in situ* concrete floor types[7]. The results were based on field studies involving over 400 dwellings. Studies in 44 US homes showed a reduction of 50 % for passive sub-slab depressurisation[8]. Two-week tests were conducted in each home with the discharge pipe

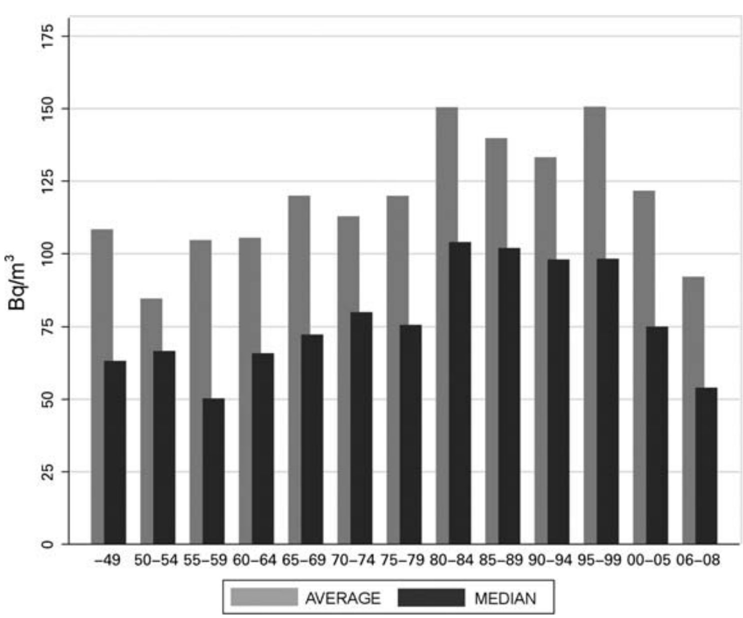

Figure 6. Radon concentration in low-rise residential houses according to the year of construction based on the national Finnish sample survey in 2006 (1949–2005). The last bar (2006–2008) represents the results of this new construction survey (2009).

capped and uncapped. The US guide for radon-resistant constructions gives an average reduction of 50 % for the passive sub-slab depressurisation system[9]. Results from the Czech Republic revealed a reduction of 40–80 % for membrane and sub-slab depressurisation[10].

In 2009, STUK carried out pilot studies in three detached houses that had a passive radon piping system. The radon concentration was measured repeatedly with the discharge pipe capped and uncapped. These preliminary results showed a decrease of 30–50 % in winter when the discharge was uncapped. These studies have been continued[5].

CONCLUSIONS

Three factors in the results of this new construction survey provide evidence of a strong impact of radon preventive measures: first, the increased prevention activity; second, the strong impact of preventive measures on radon concentrations; and third, the reduction in radon concentrations compared with the previously constructed housing stock. In addition, experimental Finnish and foreign results on the effect of passive radon piping support the results. Analysis of the Finnish indoor radon database also supports the decrease in radon concentrations observed in this study.

Estimates of the impact of preventive measures are subject to uncertainty due to the method of comparison and inaccuracies in the questionnaire data. A lower level of preventive activity among those who did not participate in the study may reduce the nationwide estimate. On the other hand, estimates of the impact would probably increase if the defects in the questionnaire data were corrected. It is also noteworthy that the implementation of preventive measures is often inadequate. Sealing of pipe penetrations in the floor slab was found to be relatively uncommon, and the sealing measures for block walls in contact with soil were generally defective. Therefore, the impact of the preventive measures will further increase as the experience of construction companies develops.

According to the results of this study, preventive activities vary widely between different areas of the country. Local authorities commonly require prevention measures in those areas with the highest radon concentrations, which has also resulted in a considerable decrease in indoor radon concentrations. On the other hand, in those areas where no prevention has been carried out, indoor radon concentrations have remained as before or have even increased. Radon-resistant new construction practices represent economic investments that also have advantageous effects in reducing moisture levels. Prevention measures may also reduce the entry of other harmful substances from soil into living spaces. The effect of passive radon piping is so significant that installation of the piping is recommended throughout the country. Builders should require architects and all participants in building projects to implement radon preventive measures according to the current guidelines.

The building code for radon prevention and the associated practical guidelines were revised in Finland in 2003–2004. Increased preventive activity and revised practices have reduced the indoor radon concentrations in houses receiving building permission in 2006 by tens of percent in comparison with houses built earlier. The requirement for radon prevention in connection with the application for building permission and the widespread and skilled implementation of preventive measures throughout the country could result in an average 50 % reduction in indoor radon concentrations compared with the present housing stock with no prevention. This would considerably reduce exposure to radon and the harmful health effects of indoor radon in the coming decades.

ACKNOWLEDGEMENTS

Questionnaire data of EU RADPAR project (Executive Agency for Health and Consumers) has been utilised in comparison with other surveys.

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